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Site Evaluation for Application of Fuel Cell Technology

U.S. Army Soldier Systems Center

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Foreword

In fiscal years 93 and 94, Congress provided funds for natural gas utilization equipment, part of which was specifically designated for procurement of natural gas fuel cells for power generation at military installations. The purchase, installation, and ongoing monitoring of 30 fuel cells provided by these appropriations has come to be known as the "DoD Fuel Cell Demonstration Program." Additional funding was provided by: the Office of the Deputy Under Secretary of Defense for Industrial Affairs & Installations, ODUSD (IA&I)/HE&E; the Strategic Environmental Research & Development Program (SERDP); the Assistant Chief of Staff for Installation Management (ACSIM); the U.S. Army Center for Public Works (CPW); the Naval Facilities Engineering Service Center (NFESC); and Headquarters (HQ), Air Force Civil Engineer Support Agency (AFCESA).

This report documents work done at U.S. Army Soldier Systems Center, Natick, MA. Special thanks is owed to the U.S. Army Soldier Systems Center points of contact (POCs), David Duncan, Paul Willwerth, and Mike Plante for providing investigators with access to needed information for this work. The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Michael J. Binder. Part of this work was performed by Science Applications International Corp. (SAIC), under Contract DACA88-94-D-0020, task orders 0002, 0006, 0007, 0010, and 0012. The technical editor was William J. Wolfe, Information Technology Laboratory. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche, CEERD-CV-T. The Acting Director of CERL is William D. Goran.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL James S. Weller.

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1 Introduction

Background

Fuel cells generate electricity through an electrochemical process that combines hydrogen and oxygen to generate direct current (DC) electricity. Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Air emissions from fuel cells are so low that several Air Quality Management Districts in the United States have exempted fuel cells from requiring operating permits. Today's natural gas-fueled fuel cell power plants operate at electrical conversion efficiencies of 40 to 50 percent; these efficiencies are predicted to climb to 50 to 60 percent in the near future. In fact, if the heat from the fuel cell process is used in a cogeneration system, efficiencies can exceed 85 percent. By comparison, current conventional coal-based technologies operate at efficiencies of 33 to 35 percent.

Phosphoric Acid Fuel Cells (PAFCs) are in the initial stages of commercialization. While PAFCs are not now economically competitive with other more conventional energy production technologies, current cost projections predict that PAFC systems will become economically competitive within the next few years as market demand increases.

Fuel cell technology has been found suitable for a growing number of applications. The National Aeronautics and Space Administration (NASA) has used fuel cells for many years as the primary power source for space missions and currently uses fuel cells in the Space Shuttle program. Private corporations have recently been working on various approaches for developing fuel cells for stationary applications in the utility, industrial, and commercial markets. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have successfully executed several research and demonstration work units with a total funding of approximately $55M.

As of November 1997, 30 commercially available fuel cell power plants and their thermal interfaces have been installed at DoD locations, CERL managed 29 of these installations. As a consequence, the Department of Defense (DoD) is the

owner of the largest fleet of fuel cells worldwide. CERL researchers have developed a methodology for selecting and evaluating application sites, have supervised the design and installation of fuel cells, and have actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers. This accumulated expertise and experience has enabled CERL to lead in the advancement of fuel cell technology through major efforts such as the DoD Fuel Cell Demonstration, the Climate Change Fuel Cell Program, research and development efforts aimed at fuel cell product improvement and cost reduction, and conferences and symposiums dedicated to the advancement of fuel cell technology and commercialization.

This report presents an overview of the information collected at U.S. Army Soldier Systems Center, Natick, MA along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report (Table 1).

Objective

The objective of this work was to evaluate U.S. Army Soldier Systems Center as a potential location for a fuel cell application.

Approach

On 16 and 17 December 1993, Science Applications International Corporation (SAIC) visited Natick RD&E Center (the Site) to investigate it as a potential location for a 200 kW phosphoric acid fuel cell. This report presents an overview of information collected at the Site along with a conceptual fuel cell installation layout and potential benefits. The Appendix to this report contains a copy of the site evaluation form filled out at the Site.

Table 1. Companion ERDC/CERL site evaluation reports.

Location	Report No.
Pine Bluff Arsenal, AR	TR 00-15
Naval Oceanographic Office, John C. Stennis Space Center, MS	TR 01-3
Fort Bliss, TX	TR 01-13
Fort Huachuca, AZ	TR 01-14
Naval Air Station Fallon, NV	TR 01-15
Construction Battalion Center (CBC), Port Hueneme, CA	TR 01-16
Fort Eustis, VA	TR 01-17
Watervliet Arsenal, Albany, NY	TR 01-18
911th Airlift Wing, Pittsburgh, PA	TR 01-19
Westover Air Reserve Base (ARB), MA	TR 01-20
Naval Education Training Center, Newport, RI	TR 01-21
U.S. Naval Academy, Annapolis, MD	TR 01-22
Davis-Monthan AFB, AZ	TR 01-23
Picatinny Arsenal, NJ	TR 01-24
U.S. Military Academy, West Point, NY	TR 01-28
Barksdale Air Force Base (AFB), LA	TR 01-29
Naval Hospital, Naval Air Station Jacksonville, FL	TR 01-30
Nellis AFB, NV	TR 01-31
Naval Hospital, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, CA	TR 01-32
National Defense Center for Environmental Excellence (NDCEE), Johnstown, PA	TR 01-33
934th Airlift Wing, Minneapolis, MN	TR 01-38
Laughlin AFB, TX	TR 01-41
Fort Richardson, AK	TR 01-42
Kirtland AFB, NM	TR 01-43
Subase New London, Groton, CT	TR 01-44
Little Rock AFB, AR	TR 01-47
U.S. Army Soldier Systems Center, Natick, MA	TR 01-49
Edwards AFB, CA	TR 01-Draft
Naval Hospital, Marine Corps Base Camp Pendleton, CA	TR 01-Draft

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

1 ft	=	0.305 m
1 mile	=	1.61 km
1 acre	=	0.405 ha
1 gal	=	3.78 L
°F	=	°C (X 1.8) + 32

2 Site Description

Natick RD&E Center is located approximately 25 miles west of Boston, MA. The climate is typical of the Northeast portion of the United States with temperatures in the teens in the winter and the 80s and 90s in the summer. The Site consists of primarily research facility buildings.

In initial discussions with Site personnel, two facilities were considered for possible fuel cell siting. The first was a food engineering research facility. After further scrutiny of the thermal load, this Site was eliminated from consideration. The second facility was the boiler plant, which is used to distribute steam throughout the Site for space heating and absorption cooling. While the operating hours were approximately the same as the food engineering facility, the thermal load was estimated to be much larger. The boiler plant was therefore chosen as the primary facility of choice for evaluating a fuel cell installation.

The boiler plant is a two story facility, which measures approximately 90 X 48 ft (8,640 sq ft). The facility is manned 24 hr per day, although the boilers only operate 9 to 11 hr per day, Monday through Friday. Electric bills for the boiler plant were not available, however, the building demand had recently been monitored and these data were obtained. Figure 1 presents the half-hourly load profile of the boiler plant for a 1-week period beginning 15 December 1993. As can be seen in the chart, the facility has a base electric load of approximately 95 kW. When the boilers are turned on in the morning, the electric load averages around 120 kW for a 9 to 11-hr period. The boilers do not operate on weekends (generally) as can be seen in Figure 1.

Site Layout

The boiler plant is a two story building. Upstairs is an office, a storage room and three 981 hp boilers built by George Allen & Sons in 1953. Downstairs is the electrical room, an auxiliary boiler, water softeners, feedwater storage and various pumps. Figure 2 presents the layout for the boiler plant.

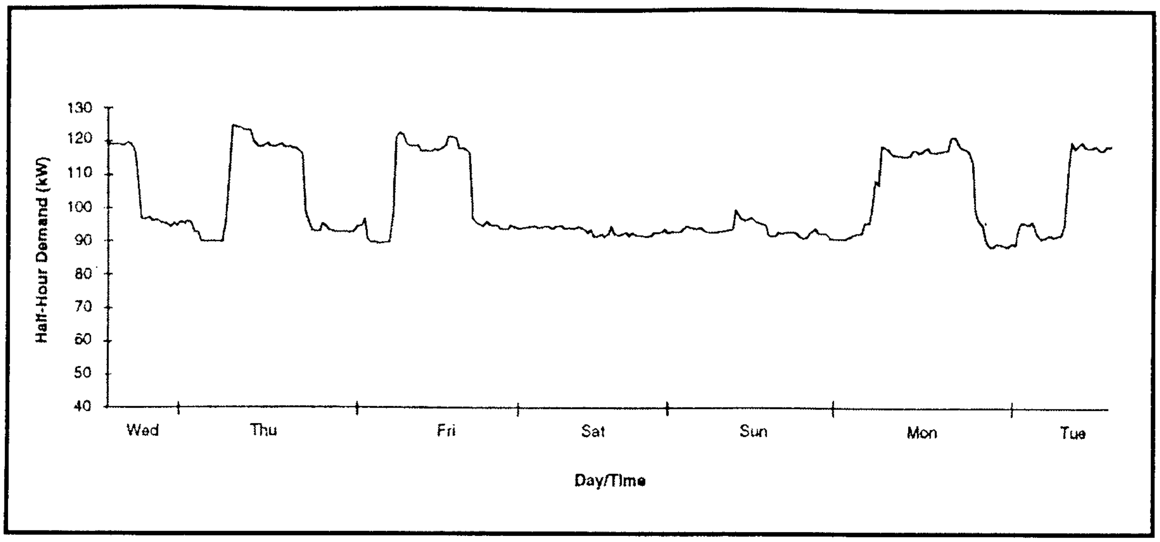

Figure 1. Boiler plant electrical demand, 15 Dec 93 – 21 Dec 93.

Electrical System

The electrical room has three transformers. Power comes into the facility at 13,800V. The power is then transformed down to either 2400 or 480V. The 2400-V (225 kVA) transformer is used for the emergency fire pump system. The 480-V (300 kVA) transformer is used for most of the pumps. A 480V–120/208V transformer supplies power to the lights and power outlets.

Steam/Hot Water System

The boiler plant operates three George Allen & Sons boilers and a small auxiliary boiler. The main boilers are 981 hp each having a surface area of 2,708 sq ft. Boiler make-up feedwater is first processed through a water softening system downstairs and then put into a 1,000-gal storage tank. As make-up water is required, water from the storage tank is pumped upstairs into the boilers to make steam. The steam is then delivered throughout the Site providing heating and cooling. Water is then returned and run through the boiler in a closed loop system.

Space Heating System

Space heating for buildings throughout the base is provided by hydronic systems located in individual buildings. Steam is supplied at 80 psi to the heating system and condensate is returned at approximately 85 °F.

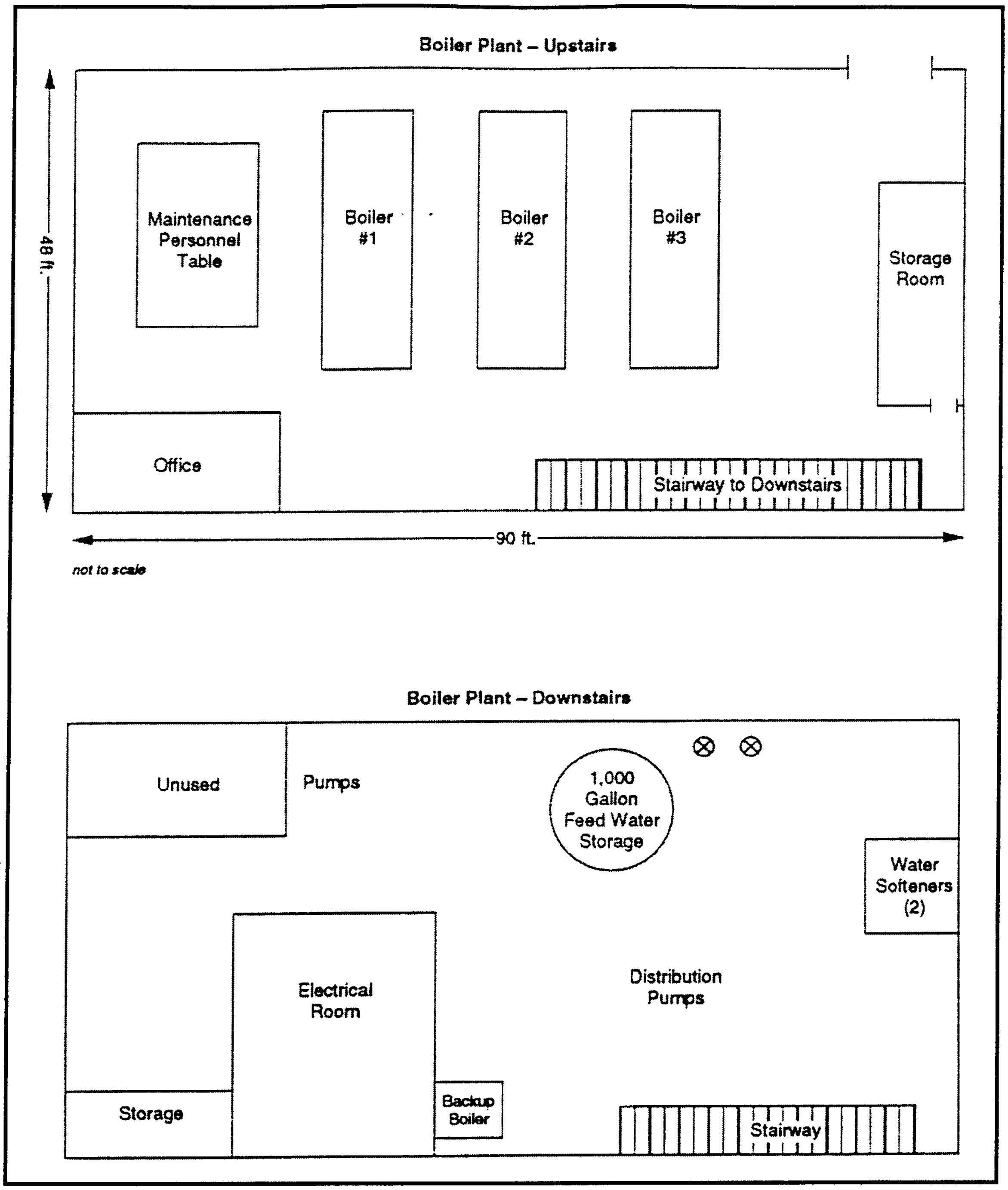

Figure 2. Boiler Plant layout.

Space Cooling System

The boiler plant supplies steam to three, 400-ton absorption chiller throughout the Site. The load accounts for much of the summer steam load. Site personnel estimate that the condensate return temperature is about 85 °F.

Fuel Cell Location

Approximately 40 ft from the boiler plant building is a fenced in area that has a small boat house. It is approximately 24 by 40 ft (960 sq ft). This Site was selected as the most attractive location for the fuel cell over two other potential locations. One was across the street in an open grassy area. This location was eliminated because it would require crossing the street for thermal and electrical interfaces as well as being too out in the open. Another location, on the back side of the building next to a parking lot, is still viable but is near an area that may have to be excavated for removal of soil contamination.

Figure 3 shows the location of the proposed fuel cell site along with proposed thermal and electric runs. It is adjacent to an electric power pole (13,800V). It is right next to the street for convenient unloading of the fuel cell. However, the power lines (at the pole) might have to be moved out of the way for craning the fuel cell into its location. Currently, the Site has a cement block building (12 by 24 ft) that would need to be torn down. Personnel from the Site indicated that they were willing to demolish the building for purposes of locating the fuel cell. It was later learned that this building was once used by the base for storage of hazardous materials. This Site must be tested for contamination before it can be approved. (Contamination would seriously delay the fuel cell installation.)

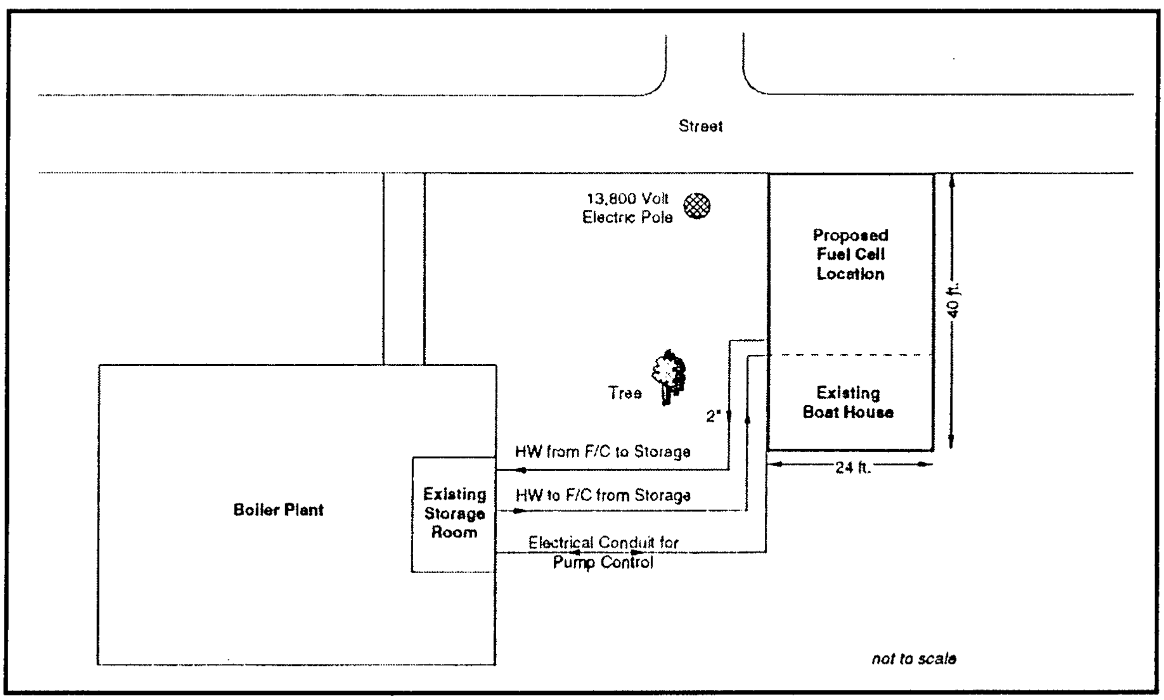

Figure 3. Fuel cell location.

Fuel Cell Interfaces

As was shown in Figure 1, the electric load of the boiler plant ranges between 90 and 130 kW. This is substantially below the 200 kW electric output of the fuel cell. It is proposed that a step-up transformer be installed with the fuel cell. The transformer would step-up the 480V output of the fuel cell and grid connect to the 13,800V service transmitted throughout the Site. Upon discussion, it was determined that the existing 13,800V-480V transformer could be used. The excess energy not used by the boiler will then be used by the other buildings on base connected to the 13,800V grid. The thermal interface into the boiler plant is proposed in two incremental loads. These include the boiler feedwater make-up load only, and the boiler feedwater make-up plus condensate return load. Each of these cases is discussed below.

The primary thermal load that was initially targeted at the site visit is the boiler make-up feedwater. Table 2 presents the boiler make-up feedwater load for the boilers between December 1992 and November 1993. The make-up water requirements ranged from a low of 18,700 gal/month in July to a high of 161,100 gal/month in November. Boiler operating hours ranged from 185 to 256 hr per month. On a monthly average basis, the boilers required from 100 to 680 gal/hr of make-up water. Assuming a 115 degree temperature rise (45 to 160 °F), the monthly average thermal requirement was 97,000 to 653,000 Btu/hr. The average thermal requirement for the make-up water during boiler operating hours for the entire year is approximately 345,000 Btu/hr.

Figure 4 presents the fuel cell thermal interface for this case. The make-up water line from the water softeners is rerouted through the fuel cell and into an intermediate storage tank. The intermediate storage tank then supplies the 1,000-gal surge tank, which is located in the bottom floor of the boiler plant. The intermediate fuel cell storage tank was sized at 1,000 gal. In the absence of thermal load profile data, a peak period of 2 hr was assumed in the morning as the boilers start up. It was also assumed that the peak load was twice the average load throughout the day. For the months October through March, the average hourly load was about 500,000 Btu/hr. Blending make-up and fuel cell storage tank water, a temperature rise of 58 °F was assumed (160 °F - (160 °F+ 45 °F)/2). The fuel cell can deliver approximately 540,000 Btu/hr based on an inlet temperature of 102 °F. The storage tank size was calculated as follows:

500,000 Btu/hr (site) * 2 hr * 2x peak = 2,000,000 Btu required for peak

2,000,000 - (2 hrs * 540,000 Btu/hr) = 920,000 Btu required for storage

920,000 Btu / (8.35 lb/gal * (160 °F – 45 °F)) = 958 gal

Table 2. Boiler operating data and energy values.

1 Date	2 Days in Month	3 Boiler Op. Days	4 Boiler Op. Hours	5 Make-up Water (Gal)	6 make-up gal/hr	7 Make-up Btu/hr	8 Return Water (gal)	9 Return gal/hr	10 Return Btu/hr
Dec-92	31	22	220	105,500	480	460,793	676,416	3,075	1,926,775
Jan-93	31	22	220	83,000	377	362,520	556,401	2,529	1,584,912
Feb-93	28	25	256	119,200	466	447,417	649,543	2,537	1,590,037
Mar-93	31	22	233	129,000	554	531,998	468,006	2,009	1,258,738
Apr-93	30	22	220	66,000	300	288,269	408,731	1,858	1,164,271
May-93	31	20	198	33,100	167	160,635	252,768	1,277	800,013
Jun-93	30	20	196	28,800	147	141,193	274,074	1,398	876,298
Jul-93	31	20	185	18,700	101	97,128	228,246	1,234	773,163
Aug-93	31	22	240	27,800	116	111,304	376,511	1,569	983,120
Sep-93	30	21	231	49,100	213	204,242	351,858	1,523	954,542
Oct-93	31	19	230	135,500	589	566,093	303,901	1,321	828,027
Nov-93	30	20	237	161,100	680	653,166	1,098,900	4,637	2,905,692
Tot/Avg	365	255	2666	956,800	359	344,856	5,645,356	2,118	1,327,000

Col. 1 = Dec- 92 and Jan-93 have estimated boiler operating hours and days
Col. 3,4,5 = from site log sheet
Col. 6 = #5 / #4
Col. 7 = #6 * 8.35 lb/gal * (160-45 °F)
Col. 8 = steam lb delivered from log book / 8.35 lb/gal - #5
Col. 9 = #8 /#4
Col. 10 = #9 * 8.35 lb/gal * (160-85 °F)

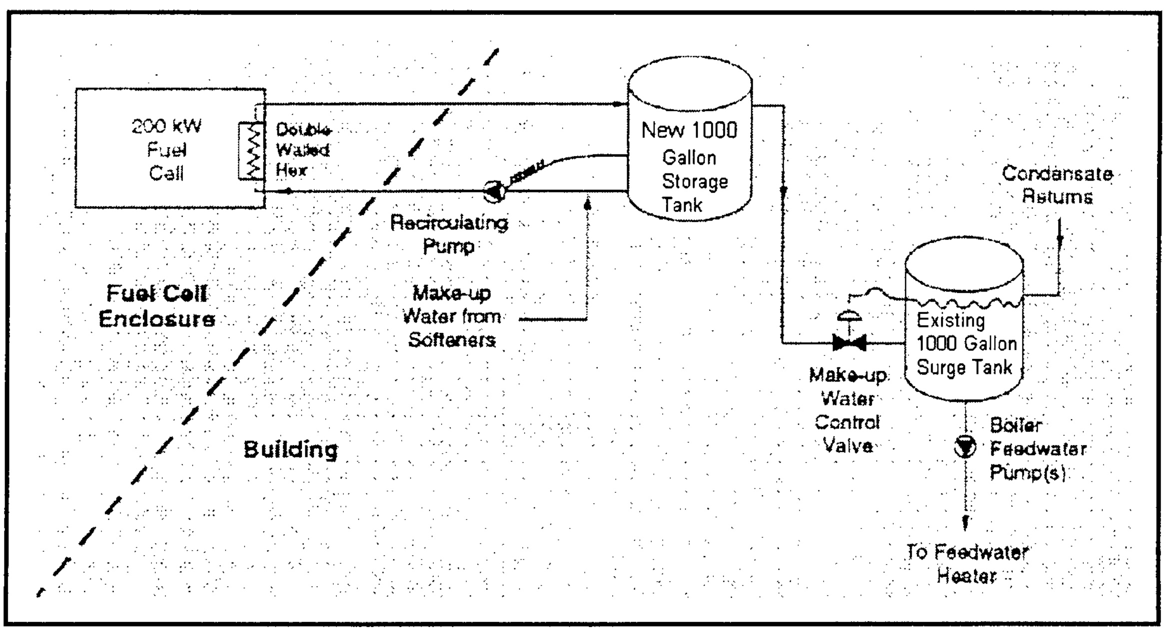

Figure 4. Fuel cell thermal interface—feedwater make-up only.

If the fuel cell heated all the boiler make-up feedwater used in a year, the fuel cell thermal output utilization would be about 17 percent. This was calculated as follows:

Fuel cell thermal utilization = 2,666 / 7,884 * 344,856 / 700,000 = 17%, where:

Boiler operating hours in a year = 2,666

Fuel cell operating hours in a year = 7,884 (90% capacity factor)

Average annual boiler Btu requirement is 344,856 Btu/operating hour

Fuel cell thermal output/hr = 700,000 Btu/operating hour

The 17 percent thermal utilization was much lower than had been originally predicted during the site visit. The primary reason for this is that it was assumed that the average boiler make-up requirement was from 6,000 to 15,000 gal per day. Site log data shows that the average annual water requirement was only about 3,700 gal per operating day.

The second thermal load examined is the feedwater make-up plus condensate return load. The Site estimated a condensate return temperature of 85 °F. Table 2 also presents the condensate return load for the boiler plant. The annual average hourly load is 1,327,000 Btu/hr, which is nearly 4 times larger than the make-up water load.

Figure 5 presents the thermal load interface for the make-up and condensate return loads. The condensate return will be heated up to only 150 °F (instead of the 160 °F for the storage tank) because a separate heat exchanger will be used to heat the condensate return. A 10 °F terminal temperature differential was assumed for the separate heat exchanger interfaced with the storage tank. A 4,000-gal storage tank is recommended, based on an average condensate load for the months of October through March of 2,685 gal/hr and storage capacity for 2 hr. The condensate return loop is interfaced with a heat exchanger located on fuel cell storage tank loop. The storage tank size was calculated as follows:

2 hr * 2,685 gal/hr * 8.35 lb/gal * (150 °F - 85 °F) = 2,914,567 Btu

2,914,567 / (8.35)(160-45) = 3,035 gal

3,035 + 958 = 3,993 gal combined storage requirement

With 4,000 gal of storage, the fuel cell thermal output will charge the storage tank for approximately 7 hr beyond the boiler operating hours. This is calculated as follows:

(4,000 gal * 8.35 lb/gal * (160-45)) / (540,000 Btu/hr) = 7.1 hr

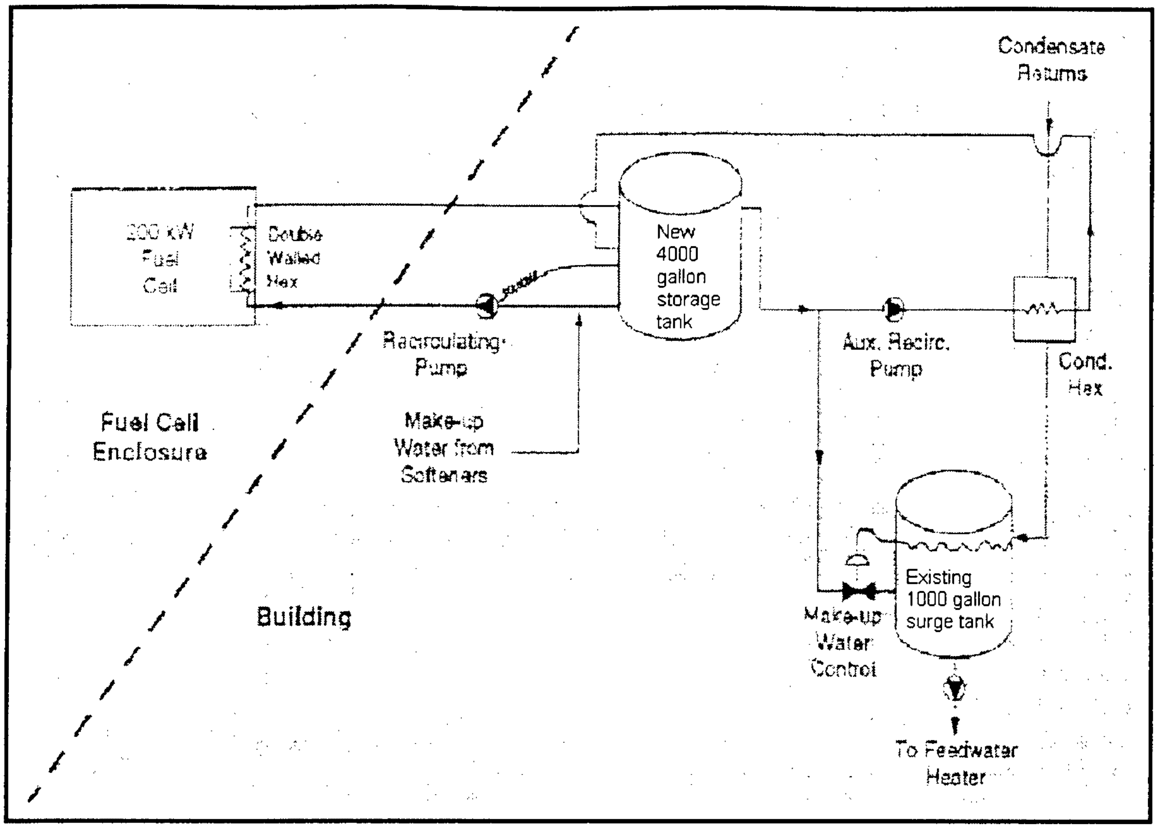

Figure 5. Fuel cell thermal interface—feedwater make-up and condensate returns.

If the fuel cell thermal output could be utilized for an additional 7 hr per boiler operating day throughout the year, this would result in an additional 1,785 hr per year (255 boiler operating days * 7 hr). Thermal utilization for this case would be as high as 56 percent (2666 hr + 1,785 hr / 7,884). Since the summer thermal requirements are roughly 60 percent of the winter load, the lower end thermal utilization for this case was assumed to be 4 hr/day. This results in a thermal utilization of about 45 percent (2,666 hr + (255 days * 4 hr) / 7884).

Figure 6 shows a layout of the alternate selected fuel cell site area (due to potential soil contamination at the originally proposed site) located 40 ft from the boiler plant, on the west side of the building.

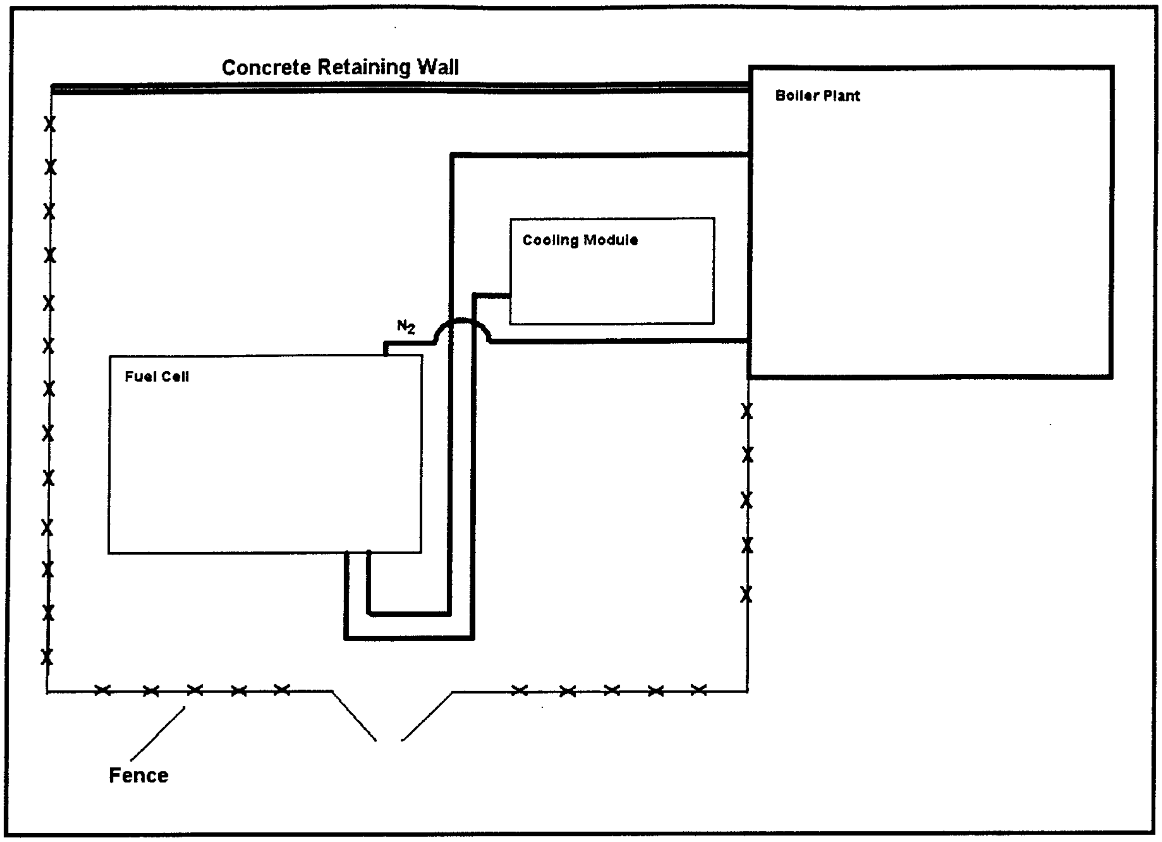

Figure 6. Fuel cell enclosure layout.

3 Economic Analysis

Energy savings were calculated based on projected energy utilization of fuel cell electrical and thermal output. Site energy rates were used as the basis for calculating fuel cell energy savings.

The Site is located in Boston Edison's service territory. Electricity bills were obtained for the months of September 1992 through July 1993 (Table 3). The Site's average electricity bills ranged from 7.5 cents/kWh in February to 10.4 cents/kWh in July. The average annual rate was 8.7 cents/kWh. The Site is billed under rate 417, which is a time-of-use rate. On-peak periods are from 8:00 a.m. to 9:00 p.m., Monday through Friday, and off-peak periods are all other times. Summer months are July through October and winter months are November through June. Actual time-of-use rates were taken from the energy bills and used in calculating the energy savings.

The Site receives natural gas from Comm Gas under rate schedule G-53. Table 4 presents the natural gas consumption and costs for the period September 1992 through July 1993. Site gas costs ranged from \$3.12/MBtu in September 1992 to \$6.07/MBtu in March 1993. The average natural gas cost for the site was \$5.23/MBtu. This average is higher than the \$4.33/MBtu average obtained from the 1991-1992 DEIS database.

Table 3. Natick RD&E Center electricity consumption.

Date	Billing Days	Peak KW	Total KWH	Total Amount	$/KWH
Jul-93	28	3,207	1,164,210	$120,873.42	$0.104
Jun-93	32	3,257	1,328,549	$130,986.27	$0.099
May-93	32	3,056	1,093,275	$99,107.31	$0.091
Apr-93	30	2,609	997,159	$79,557.02	$0.080
Mar-93	31	2,427	860,460	$71,068.71	$0.083
Feb-93	34	2,531	1,211,809	$91,097.52	$0.075
Jan-93	28	2,474	956,044	$76,643.81	$0.080
Dec-92	31	2,314	975,962	$76,619.09	$0.079
Nov-92	31	2,490	994,176	$83,201.28	$0.084
Oct-92	30	2,424	998,196	$77,451.62	$0.078
Sep-92	30	3,050	1,108,441	$104,762.44	$0.095

Table 4. Natick RD&E Center natural gas consumption.

Date	Therms	Amount	$/MBtu
Jul-93	20,100	$7,887.75	$3.92
Jun-93	19,650	$7,713.41	$3.93
May-93	10,062	$3,998.71	$3.97
Apr-93	22,837	$12,950.40	$5.67
Mar-93	30,448	$18,489.05	$6.07
Feb-93	37,240	$22,591.01	$6.07
Jan-93	33,360	$20,247.72	$6.07
Dec-92	28,831	$17,512.47	$6.07
Nov-92	27,119	$16,478.53	$6.08
Oct-92	30,625	$13,116.67	$4.28
Sep-92	23,670	$7,374.07	$3.12
Total	283,942	$148,359.79	$5.23

Table 5 lists the electricity demand and energy on-peak/off-peak rates paid by the Site during the September 1992 to July 1993 period. This table also presents the first year electricity savings from a 200 kW fuel cell based on a 90 percent electric capacity factor. It was assumed that fuel cell outage hours during the on/off-peak periods occurred at the same percentages as shown in Table 5. In other words, outage hours were not weighted more heavily in either the on-peak or off-peak periods, but were proportional to the number of period hours in the year. Total first year electricity savings using a 90 percent electric capacity factor was $114,502, which includes full demand charge savings. This works out to an average displaced electric rate of about $0.0726/kWh ($21.27/MBtu) and is slightly lower than the 1991-1992 DEIS database average of $0.079 ($22.83).

Table 5. Boston Edison rate schedule and site savings.

		Summer	Winter	
Demand	On-Peak	$16.11	$9.83	
Energy*	On-peak	$0.071	$0.060	
	Off-Peak	$0.051	$0.048	
Hours/yr	On-Peak	1,079	2,210	37.5%
	Off-Peak	1,777	3,694	62.5%
Savings/Year (90% ELF)	On-Peak	$13,789.62	$23,868.00	
	Off-Peak	$16,312.86	$31,916.16	
		$30,102.48	$55,784.16	$85,886.64
Demand (200 kW)		$12,888.00	$15.728.00	$26,616.00
Total Savings		$42,990.48	$71,512.16	$114,502.64
				$/kW = $0.0726
*Includes site fuel charge				

Based on the projected fuel cell electric capacity factor and thermal utilization for the thermal design schemes discussed above, the energy savings from a 200 kW fuel cell were calculated. Table 6 presents the electric and thermal energy savings and input natural gas costs for the fuel cell installation. For the boiler make-up feedwater only case, a total first year savings of $42,817 was calculated. This assumes a thermal utilization of only 17 percent. For the make-up and condensate return loads, estimated energy savings were $53,591 to $57,822 assuming a thermal utilization of 45 to 56 percent. Table 6 also presents the energy savings based on capturing only 50 percent of the potential demand charge savings as well as zero demand savings.

The cost of additional storage capacity for the condensate return case, including an additional storage tank capacity of 3,000 gal, piping and pump, would be approximately $12,000. The additional annual energy savings for this case is about $15,000 ($57,822-$42,817).

The analysis is a general overview of the economics. For the first 5 years, ONSI will be responsible for the fuel cell maintenance. Maintenance costs are not reflected in this analysis, but could represent a significant impact on net energy savings. Since load profile data were not available, energy savings could vary depending on actual electrical and thermal utilization.

Table 6. Economic savings of fuel cell design alternatives.

Case	ECF	TU	Displaced kWh	Displaced Gas (MBtu)	Electrical Savings	Thermal Savings	Nat. Gas Cost	Net Savings
A - Max. Thermal	90%	100%	1,576,800	7,357	$114,502	$38,477	$78,228	$74,751
A - Make-up + return (max)	90%	56%	1,576,800	4,120	$114,502	$21,548	$78,228	$57,822
A - Make-up + return (min)	90%	45%	1,576,800	3,311	$114,502	$17,317	$78,228	$53,591
A -Make-up only	90%	17%	1,576,800	1,251	$114,502	$6,543	$78,228	$42,817
B - Max. Thermal	90%	100%	1,576,800	7,357	$100,194	$38,477	$78,228	$60,443
B - Make-up + return (max)	90%	56%	1,576,800	4,120	$103,261	$21,548	$78,228	$46,581
B - Make-up + return (min)	90%	45%	1,576,800	3,311	$100,194	$17,317	$78,228	$39,283
B - Make-up only	90%	17%	1,576,800	1,251	$100,194	$6,543	$78,228	$28,509
C - Max. Thermal	90%	100%	1,576,800	7,357	$85,886	$38,477	$78,228	$46,135
C - Make-up + return (max)	90%	56%	1,576,800	4,120	$85,886	$21,548	$78,228	$29,206
C - Make-up + return (min)	90%	45%	1,576,800	3,311	$85,886	$17,317	$78,228	$24,975
C - Make-up only	90%	17%	1,576,800	1,251	$85,886	$6,543	$78,228	$14,201

Assumptions:

- Input Natural Gas Rate: $5.23 /MBtu
- Displaced Thermal Gas Rate: $5.23 /MBtu
- Displaced Electricity Rate: 417
- Fuel Cell Thermal Output: 700,000 Btu/hr
- Fuel Cell Electrical Efficiency: 36%
- Seasonal Boiler Efficiency: 75%
- CASE A: full fuel cell demand savings
- CASE B: 50% of full fuel cell demand savings
- CASE C: zero fuel cell demand savings
- ECF = Fuel cell electric capacity factor
- TU = Thermal utilization

4 Conclusions and Recommendations

Personnel from the Site and Comm Gas have expressed enthusiastic support for the idea of a 200 kW fuel cell at the U.S. Army Soldier Systems Center. This study concludes that the boiler plant is the best location for the fuel cell because it has the largest thermal load at the Site. It is recommended that the existing transformer be used to deliver the electrical output to the entire base since the boiler peak load is only about 130 kW. It is also recommended that both the feedwater make-up and condensate return loads be interfaced with the fuel cell to maximize thermal utilization of the fuel cell. A storage tank of 4,000 gal is recommended.

Due to potential soil contamination issues, an alternate site (Figure 6, p16) was selected as the fuel cell location.

The energy savings are quite favorable for this Site. A total of $114,000 in electricity and $38,000 in thermal savings are possible. Net savings range from $15,000 to $75,000 in the first year.

Appendix: Fuel Cell Site Evaluation Form

Site Name: **U.S. Army Soldier Systems Center**
Location: **Natick, MA** Contacts: **David Duncan**

1. Electric Utility: **Boston Edison** Rate Schedule: **G-3**
   Contact:

2. Gas Utility: **Commonwealth Gas** Rate Schedule:
   Contact: **Larry Decker**

3. Available Fuels: **Diesel Fuel #6** Capacity Rate:

4. Hours of Use and Percent Occupied:

Weekdays	________	Hrs.	12-14
Saturday	________	Hrs.	________
Sunday	________	Hrs.	________

5. Outdoor Temperature Range: **10 - 100 °F**

6. Environmental Issues: **Follow California standards fairly closely**

7. Backup Power Need/Requirement:

8. Utility Interconnect/Power Quality Issues:

9. On-site Personnel Capabilities: **Boiler plant operators - Gas Company will perform maintenance**

10. Access for Fuel Cell Installation: **Proposed site is right next to road**

11. Daily Load Profile Availability: **See Figure 1 (electric only)**

12. Security: **Install fence**

Site Layout

Facility Type: **Boiler Plant** Age: **30 years**

Construction: **Steel and concrete walls**

Square Feet: **8,640 sq ft (90 X 48 ft X 2 stories)**

See Figure 2

Show:

- **electrical/thermal/gas/water interfaces and length of runs**
- **drainage**
- **building/fuel cell site dimensions**
- **ground obstructions**

Electrical System

Service Rating: **13,800V into facility;**
Three transformers (2400, 480, 120/208)

Electrically Sensitive Equipment: **None**

Largest Motors (hp, usage):

Grid Independent Operation?: **No**

Steam/Hot Water System

Description: **George Allen & Sons (3) built in 1953**

System Specifications: **2,708 sq ft heating surface; saturated steam at 80 psi**

Fuel Type: **#6 fuel oil**

Max Fuel Rate: **~1,000 gal/operating day**

Storage Capacity/Type: **1,000 gal**

Interface Pipe Size/Description: **2-in. copper**

End Use Description/Profile: **Steam is sent out to entire base for space heating in the winter and drives three absorption chiller (400 tons each) in the summer. (Distributed throughout base.)**

Space Cooling System

Description: **400 ton absorption chiller on base (3)**

Air Conditioning Configuration:
- Type: **Absorption chiller**
- Rating: **400 Ton**
- Make/Model:

Seasonality Profile: **No data available (Distributed throughout base.)**

Space Heating System

Description: **Hydronic system throughout base**

Fuel: **#6 fuel oil**

Rating: **~1,000 gal/operating day**

Water supply Temp: **saturated steam @ 80 psi**

Water Return Temp: **~ 85 °F**

Make/Model:

Thermal Storage (space?): **only for condensate return**

Seasonality Profile: **None available. Distributed Throughout Base**

Billing Data Summary

ELECTRICITY

	Period	kWh	kW	Cost
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10				
11.				
12.				

NATURAL GAS

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

OTHER

	Period	Consumption	Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			
12.			

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14. ABSTRACT

Fuel cells are an environmentally clean, quiet, and a highly efficient method for generating electricity and heat from natural gas and other fuels. Researchers at the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) have actively participated in the development and application of advanced fuel cell technology since fiscal year 1993 (FY93), and have selected and evaluated application sites, supervised the design and installation of fuel cells, actively monitored the operation and maintenance of fuel cells, and compiled "lessons learned" for feedback to manufacturers for 29 of 30 commercially available fuel cell power plants and their thermal interfaces installed at Department of Defense (DoD) locations.

This report presents an overview of the information collected at U.S. Army Soldier Systems Command, Natick, MA, along with a conceptual fuel cell installation layout and description of potential benefits the technology can provide at that location. Similar summaries of the site evaluation surveys for the remaining 28 sites where CERL has managed and continues to monitor fuel cell installation and operation are available in the companion volumes to this report.

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